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Dominion®

January 28, 2011

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D. C. 20555

Serial No. NA3-10-035R
Docket No. 52-017
COL/DWL

DOMINION VIRGINIA POWER
NORTH ANNA UNIT 3 COMBINED LICENSE APPLICATION
SRP 02.05.02: RESPONSE TO RAI LETTER 53

On December 21, 2010, the NRC requested additional information to support the review of certain portions of the North Anna Unit 3 Combined License Application (COLA). The responses to the following RAI Questions are provided in Enclosures 1 and 2:

- RAI 5198, Question 02.05.02-1 Justify GMRS determination and describe site response analysis
- RAI 5199, Question 02.05.02-2 Address variability of rock elevations and the applicability of 1-D analysis methods

Although a complete response to RAI 02.05.02-1 is provided, the associated markups are not enclosed. Additional time and significant coordination is required to ensure that the COLA text, tables, and figures impacted by the response present accurate and complete information. The markups will be provided on or before March 25, 2011. The information from these responses will be incorporated into a future submission of the COLA, as described in the enclosures.

Please contact Regina Borsh at (804) 273-2247 (regina.borsh@dom.com) if you have questions.

Very truly yours,

Eugene S. Grecheck

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NRO

Enclosures:

1. Response to RAI Letter Number 53, RAI 5198 Question 02.05.02-1
2. Response to RAI Letter Number 53, RAI 5199 Question 02.05.02-2

Commitments made by this letter:

1. Provide the markup COLA sections identified in the response to RAI Question 02.05.02-1 by March 25, 2011.
2. Incorporate proposed changes in a future COLA submission.

COMMONWEALTH OF VIRGINIA

COUNTY OF HENRICO

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Eugene S. Grecheck, who is Vice President-Nuclear Development of Virginia Electric and Power Company (Dominion Virginia Power). He has affirmed before me that he is duly authorized to execute and file the foregoing document on behalf of the Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 28th day of January, 2011
My registration number is 7173057 and my
Commission expires: August 31, 2012

Wanda K. Marshall
Notary Public

WANDA K. MARSHALL
Notary Public
Commonwealth of Virginia
7173057
My Commission Expires Aug 31, 2012

cc: U. S. Nuclear Regulatory Commission, Region II
C. P. Patel, NRC
T. S. Dozier, NRC
J. T. Reece, NRC

ENCLOSURE 1

Response to NRC RAI Letter 53

RAI 5198 Question 02.05.02-1

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

North Anna Unit 3

Dominion

Docket No. 52-017

RAI NO.: 5198 (RAI Letter 53)

SRP SECTION: 02.05.02 – VIBRATORY GROUND MOTION

QUESTIONS for Geosciences and Geotechnical Engineering Branch 2 (RGS2)

DATE OF RAI ISSUE: 12/21/2010

QUESTION NO.: 02.05.02-1

FSAR Section 2.5.2.5 states that the GMRS is defined at a site elevation of 135 ft below finished grade at the hard rock interface (Vs = 9200 ft/sec). Justify that this location for the GMRS is consistent with the description of the SSE found in 10 CFR 100.23(d)(1) and the location of the GMRS as specified in ISG-17 and RG 1.208, which states that

> The horizontal and vertical GMRS are determined in the free-field on the ground surface. For sites with soil layers near the surface that will be completely excavated to expose competent material, the GMRS are specified on the outcrop or hypothetical outcrop that will exist after excavation.

As the weathered rock above the hard rock interface has a Vs less than 9200 ft/sec, please provide the base Vs profile along with a complete description of the site response analysis to determine the GMRS for the site.

<u>Dominion Response</u>

After discussions with the NRC on this topic, Dominion has decided to revise the current location of the Ground Motion Response Spectra (GMRS) provided in FSAR Section 2.5.2.5 from Elevation 145 ft to a free field hypothetical outcrop at Elevation 250 ft. (Note that the elevation of 135 ft below finished grade is incorrectly stated in the above question. Also, all elevations provided within are with respect to NAVD 88 and that the design plant grade is at Elevation 290 ft.) At Elevation 250 ft, the top layer of the rock column is Zone III-IV material, a moderately weathered to slightly weathered rock. The Shear Wave Velocity (V_S) profile for the site response analyses is provided in Figure 1. Elevation 250 ft corresponds closely to the bottom of the foundation of the Reactor

Building Complex (R/B) and the Power Source Buildings (PS/Bs). The actual foundation bases are at Elevation 251 ft. This is the lowest foundation elevation of the Seismic Category I structures. Note that for the R/B and the PS/Bs [as well as the Power Source Fuel Storage Vaults (PSFSVs)], the excavation will be extended below the bottom of each foundation elevation to remove and replace the Zone II and Zone III material with lean concrete fill. The revised GMRS is calculated as a geologic outcrop response spectra in accordance with the guidance specified in ISG-17 and RG 1.208.

Consistent with the FIRS calculation methodology presented in FSAR Section 3.7.1, the calculation of the revised GMRS is carried out in the following steps:

1. A total of 60 simulated rock profiles are generated to incorporate the variability of the dynamic rock properties at the site. FSAR Section 2.5.4.2 provides the static and dynamic soil and rock properties including shear wave velocity profiles, soil and rock layer thicknesses, unit weights, Poisson's ratios, and damping ratios. The properties of the different rock layers considered for the GMRS calculation provide the best estimate (BE) properties and an estimate of the variation of these properties. Note that the Zone III-IV rock, and the Zone IV rock, which constitute the subsurface material profiles above the bedrock for the GMRS calculation, are assigned linear properties (strain-independent shear modulus and damping). Profile simulation accounts for the variation of the shear wave velocities and damping ratios, as well as the thicknesses of the different layers to generate 60 simulated profiles.

2. The low frequency (LF) and high frequency (HF) input hard rock spectra presented in FSAR Section 2.5.2.6.7, Figure 2.5-202, are applied at bedrock having a shear wave velocity of 9,200 ft/sec. The spectra are then propagated from bedrock to the GMRS elevation through the sets of 60 simulated profiles to determine the log-mean site acceleration response spectra (ARS) and log-mean amplification functions using the computer program P-SHAKE. Note that in this case the truncated soil column response (TSCR) analysis to obtain the geologic outcrop is calculated without any further iteration since the shear modulus and damping ratios for the site profiles are considered strain-independent.

3. The horizontal GMRS are calculated by enveloping the LF and HF log-mean 5 percent damping ARS at the GMRS elevation. The horizontal GMRS is scaled by an appropriate V/H scaling function to obtain the corresponding vertical GMRS. For this calculation, the V/H function is that presented in FSAR Section 2.5.2.6 and Table 2.5-201.

Because both the current and revised GMRS are realizations of free surface ground motions simply specified at different elevations within a single site-specific representative subsurface rock column, they are consistent with each other as well as with other design motions developed within that subsurface profile. That is, the recharacterization of the GMRS at a different elevation provided above does not affect the design motions described in Section 3.7.1 of the FSAR.

The new GMRS will be reflected in a revision to FSAR Table 2.5-201 and Figure 2.5-201. The revised horizontal and vertical GMRS are presented in Figure 2 and Figure 3, respectively. For comparison purposes the LF and HF input rock spectra (for horizontal direction only) as well as the U.S. APWR CSDRS are also shown in these figures. The numerical values for the horizontal and vertical GMRS at selected frequencies are provided in Table 1.

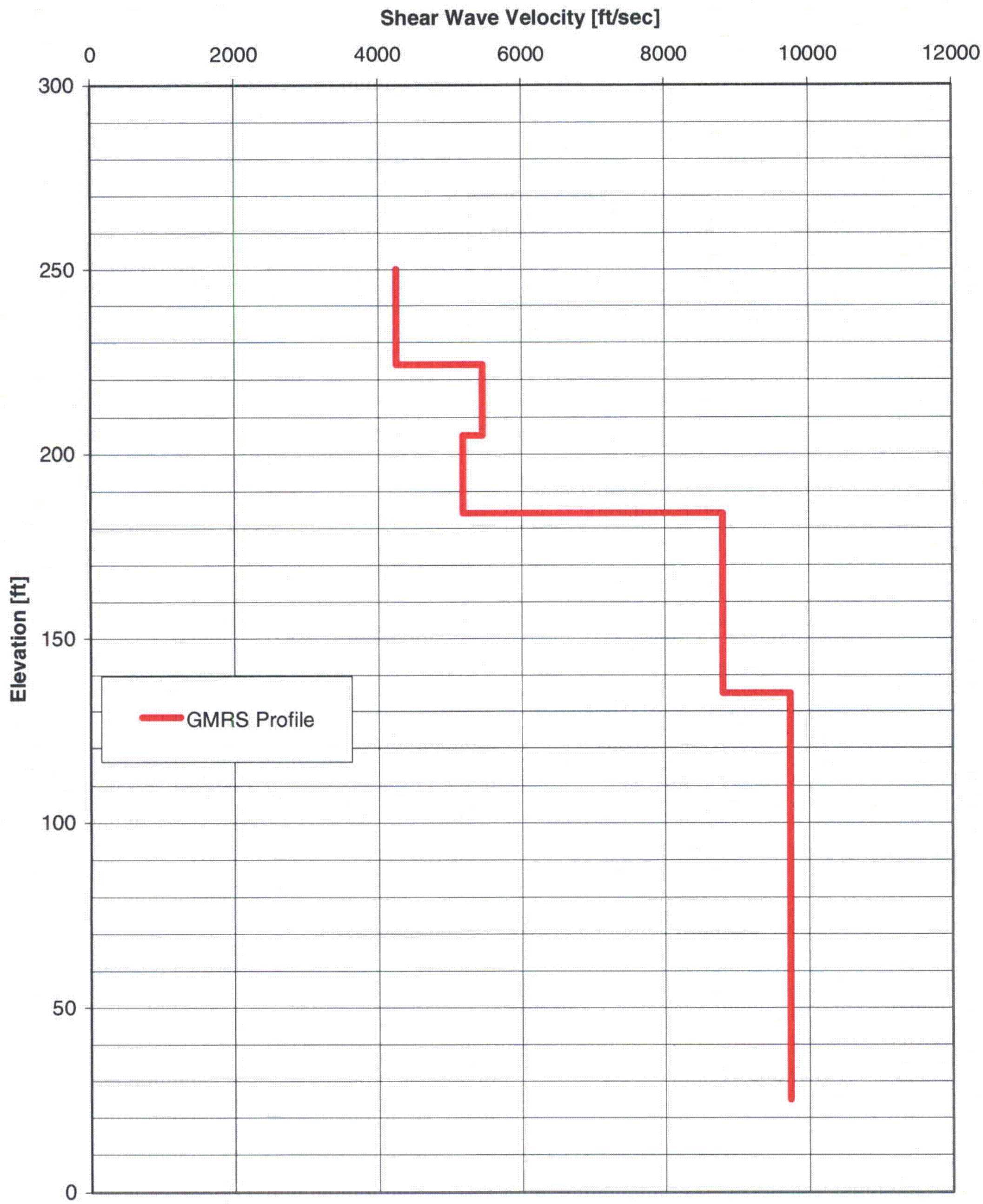

Figure 1. Best Estimate Shear Wave Velocity Profile for GMRS Calculation

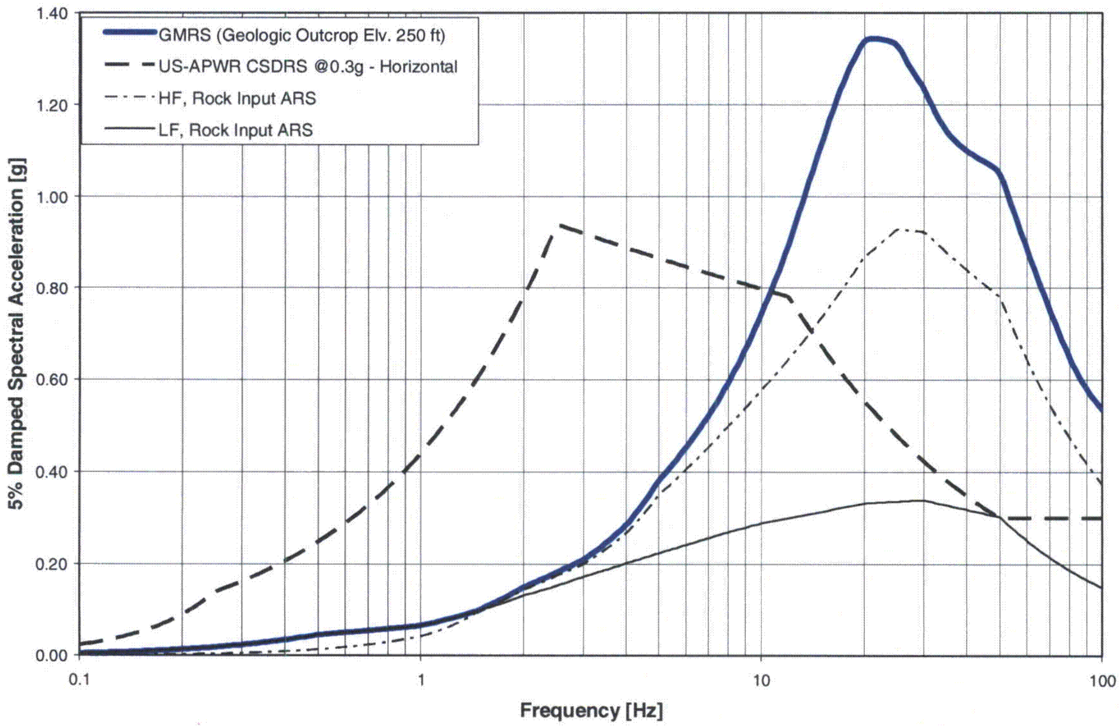

Figure 2. Revised Horizontal GMRS for NA3

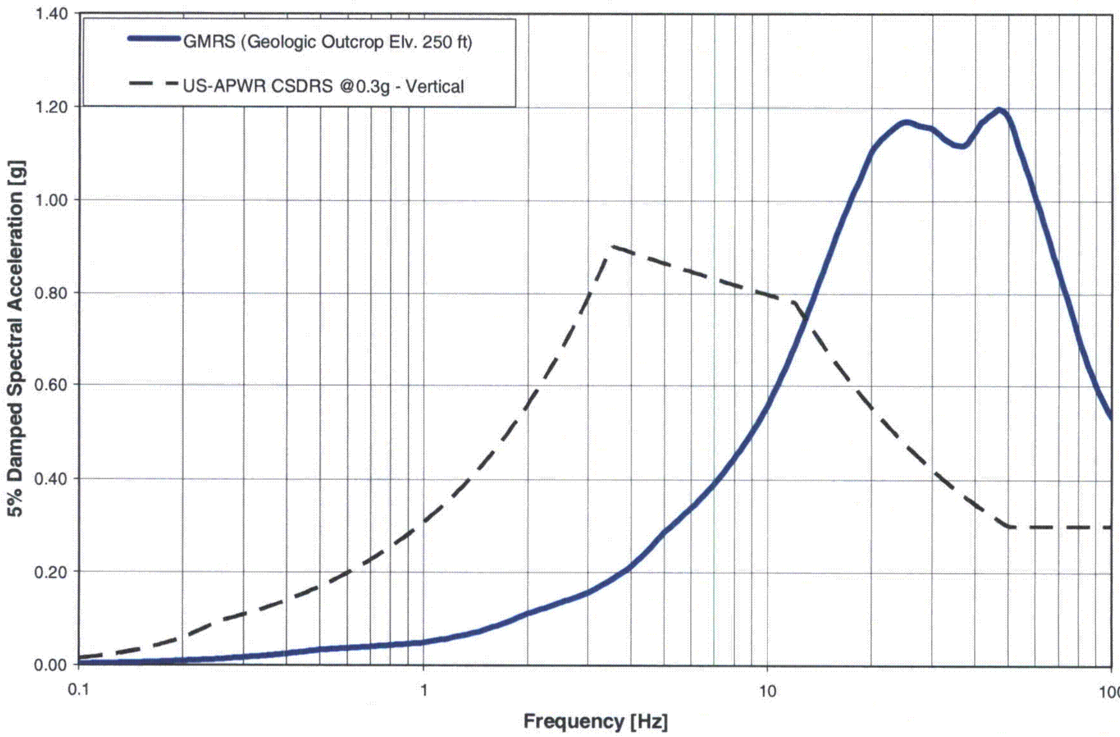

Figure 3. Revised Vertical GMRS for NA3

Table 1. Tabulated Horizontal and Vertical GMRS Acceleration Values for 38 Selected Frequencies

Frequency [Hz]	Horizontal GMRS [g]	V/H Spectral Ratio	Vertical GMRS [g]
100	0.535	1.00	0.535
90.0	0.579	1.04	0.600
80.0	0.648	1.09	0.706
70.0	0.752	1.13	0.848
60.0	0.886	1.14	1.007
50.0	1.049	1.12	1.180
45.0	1.077	1.10	1.187
40.0	1.101	1.04	1.148
35.0	1.143	0.98	1.121
30.0	1.233	0.94	1.155
25.0	1.328	0.88	1.169
20.0	1.337	0.83	1.104
15.00	1.116	0.79	0.879
12.50	0.935	0.77	0.721
10.00	0.744	0.75	0.558
9.00	0.667	0.75	0.500
8.00	0.595	0.75	0.446
7.00	0.522	0.75	0.391
6.00	0.453	0.75	0.340
5.00	0.382	0.75	0.286
4.00	0.284	0.75	0.213
3.00	0.210	0.75	0.1574
2.50	0.1821	0.75	0.1366
2.00	0.1499	0.75	0.1124
1.500	0.1026	0.75	0.0769
1.250	0.0833	0.75	0.0625
1.000	0.0659	0.75	0.0494
0.900	0.0622	0.75	0.0467
0.800	0.0585	0.75	0.0439
0.700	0.0545	0.75	0.0409
0.600	0.0502	0.75	0.0376
0.500	0.0451	0.75	0.0339
0.400	0.0339	0.75	0.0254
0.300	0.0230	0.75	0.01727
0.200	0.01295	0.75	0.00971
0.150	0.00807	0.75	0.00605
0.125	0.00598	0.75	0.00448
0.100	0.00414	0.75	0.00311

Proposed COLA Revision

Although a complete response to RAI 02.05.02-1 is provided, the associated markups are not enclosed. Additional time and significant coordination is required to ensure that the COLA text, tables, and figures impacted by the response present accurate and complete information. The markups will be provided on or before March 25, 2011.

The following North Anna Unit 3 COLA sections will be revised:

- Part 2, FSAR Table 2.0-201, "Vibratory Ground Motion" Evaluation
- Part 2, FSAR Section 2.5.2, "Vibratory Ground Motion"
- Part 2, FSAR Table 2.5-201, "Selected Horizontal Ground Motion Response Spectrum Amplitudes, V/H Spectral Ratios, and Resulting Vertical Ground Motion Response Spectrum Amplitudes"
- Part 2, Figure 2.5-201, "Horizontal and Vertical Ground Motion Response Spectra (GMRS)"
- Part 2, Figure 2.5-202, "High-Frequency and Low-Frequency Hard Rock Horizontal Response Spectra"
- Part 2, FSAR Section 3.7, "Seismic Design"
- Part 2, FSAR Figure 3.7-203, "GMRS and Geologic Outcrop FIRS at Bottom of Basemat – Horizontal"
- Part 2, FSAR Figure 3.7-204, "GMRS and Geologic Outcrop FIRS at Bottom of Basemat – Vertical"
- Part 7, Departures Report, Departure NAPS DEP 3.7(2), "Site Amplification Functions and Site Response Analysis"
- Part 7, Departures Report, Variance NAPS ESP VAR 2.0-4, "Vibratory Ground Motion"

ENCLOSURE 2

Response to NRC RAI Letter 53

RAI 5199 Question 02.05-02-2

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

North Anna Unit 3

Dominion

Docket No. 52-017

RAI NO.: 5199 (RAI Letter 53)

SRP SECTION: 02.05.02 – VIBRATORY GROUND MOTION

QUESTIONS for Geosciences and Geotechnical Engineering Branch 2 (RGS2)

DATE OF RAI ISSUE: 12/21/2010

QUESTION NO.: 02.05.02-2

FSAR Section 2.5.2.5 Seismic Wave Transmission Characteristics of the Site and 2.5.4.2 Description of Subsurface Materials of the North Anna Site, Figures 2.5-209-210 and Figures 2.5-229-234 demonstrate significant variability in the elevation of the top of competent rock and layer thicknesses at the site under the reactor building complex and other category I structures. Figure 2.5-237 also shows large variations in the shear-wave velocity along the site. Methods of site response calculations including Approach 2 and Approach 3 (see NUREG/CR-6728) used to perform site response analyses are based on one dimensional subsurface structure approximation, or in other words, flat layer structure.

a) Please justify the assumption of uniformity of layers based on available borings and shear-wave velocity profiles in relation to applicability of 1-D methods such as SHAKE and P-SHAKE to determine the North Anna site amplification.

b) Please describe how the site response analyses for the FIRS and GMRS will adequately capture the significant variability in the top of competent rock across not only the site, but also across the footprint of the Reactor Building and other seismic Category I structures.

Dominion Response

Background

Zone IV and Zone III-IV Rock

Although the top of rock contours depicted in FSAR Figures 2.5-209 (Zone IV) and 2.5-210 (Zone III-IV) show distinct variation in elevation across the site, it is important to note that these zones consist of the same bedrock material, i.e., the site is not made up of layers of different rock types, nor are there dipping layers. The distinction between Zone IV (very strong rock) and Zone III-IV (strong rock) is in the degree of weathering, with Zone IV designated as slightly weathered to fresh and Zone III-IV designated as moderately to slightly weathered.

In the North Anna Unit 3 (NA3) borings, the decision to classify the rock core as Zone III-IV or Zone IV is based to some extent on the visual description of the core, but greater weight is placed on the rock quality designation (RQD) because it is a quantitative parameter. Rock core runs with a RQD between 50% and 90% are designated Zone III-IV and those with a RQD greater than 90% are designated Zone IV. In many borings, Zone III-IV cores alternate with Zone IV cores based on RQD, and thus designating a boundary between the zones is difficult.

In summary, although the top of rock contours in FSAR Figures 2.5-209 and 2.5-210 clearly show variation (and similarly the profiles in FSAR Figures 2.5-229 through 234, especially with the 2:1 vertical exaggeration within these figures), the variation is more random than the figures suggest, the rock material within each zone is the same, and both zones consist of high quality bedrock.

Zone III and Concrete Fill

Zone III is generally found above Zone III-IV in the rock profile and is classified as weathered rock with a RQD less than 50% and an average RQD of about 20%. Much of the variation in shear wave velocity (V_s) shown in FSAR Figure 2.5-237 is due to the varying degree of weathering in Zone III. V_s values below about 4,000 ft/sec are generally from Zone III material. All Zone III rock will be removed (by ripping) from beneath the reactor building complex (R/B), the power source buildings (PS/Bs) and the power source fuel storage vaults (PSFSVs), and replaced with lean concrete fill.

Details of the concrete fill are provided in FSAR Section 2.5.4.2.5, which indicates if the top 25 ft of Zone III rock beneath the R/B is replaced with concrete, the seismic response at foundation level decreases with increasing V_s of the concrete. Based on the calculated log-mean V_s values at and below the R/B foundation (shown for three borings in FSAR Figure 2.5-241a), the V_s of the in-situ rock at 25 ft below the R/B foundation base is approximately 5,000 ft/sec. Therefore, the V_s of the concrete fill should be equal to or greater than 5,000 ft/sec to ensure that the seismic response of the column that includes the concrete fill is equal to or less than the response from the in-situ rock. Concrete fill with design strength of 2,500 psi will be used. Analysis indicates that this will have a V_s of at least 6,300 ft/sec. The average V_s of the concrete fill is taken as 7,000 ft/sec. Note that the V_s range for the underlying Zone III-IV material is 4,000 to 8,000 ft/sec.

In summary, all of the Zone III weathered rock will be excavated from below the R/B, PS/Bs and PSFSVs. It will be replaced by concrete fill that will have similar V_s values to the underlying Zone III-IV bedrock. The response analysis approach used for this profile is described below in the response to Question (a).

Response to Question (a)

Each 1-D analysis, by definition, assumes uniform soil profile layers in horizontal directions. The variation of the soil layer thickness and other dynamic properties are included in the site response analysis through the soil profile simulation and repeated 1-D analysis using simulated profiles. The response analysis for the R/B will be used as an example since it is typical of the 1-D analysis that was performed. The R/B foundation is 309 ft x 213 ft in plan view with an embedment depth of 39 ft. As a result, the base of the mat foundation is at Elevation 251 ft (all elevations provided within are with respect to NAVD 88). Based on the top of competent rock (Zone III-IV) contours in FSAR Figure 2.5-210, the minimum contour below the structure is El. 220 ft, although there may be isolated areas that are lower (e.g., boring W-1 shows Zone III-IV hard rock as high as El. 229 ft, but RQD does not occur consistently above 50% until El. 211 ft). The range of concrete fill thickness beneath the R/B was taken as 1 ft to 33 ft, with an average thickness of 15.5 ft.

The shear wave velocity profile in Figure 1 was obtained from the three V_s borings within and close to the R/B footprint (B-901, B-907 and B-909 in FSAR Figure 2.5-237). The log mean of this V_s profile is shown in Figure 1. This figure also shows the best estimate of the shear wave velocity used for the R/B (bold solid line). It shows the backfill (V_s of around 1,000 ft/sec) from grade at El. 290 ft down to the foundation base at El. 251 ft, then 15.5 ft of concrete at average V_s of 7,000 ft/sec, underlain by Zone III-IV and then Zone IV bedrock.

The site response analysis for the calculation of the Foundation Input Response Spectra (FIRS) and Soil Structure Interaction (SSI) input motion spectra is preceded by a soil profile simulation that generates a set of 60 randomized profiles. These randomized profiles consider both the variation in the soil and rock stratum properties (shear-wave velocity, damping ratio, and soil strain-dependent nonlinearity relationships) and the observed range of variation in the stratum thicknesses across the footprint of the subject structure. For example, the concrete thickness in the simulated profiles for the R/B ranged from 1 ft to 33 ft. The V_s profile was varied using a function of the estimated standard deviation for each soil/rock stratum. Figure 2 shows the V_s for the 60 simulated profiles for the R/B Complex, including the input best estimate profile (from Figure 1) and the simulated median. These profiles were used as input to P-SHAKE to generate the FIRS and SSI input motion spectra for the R/B.

In summary, the assumption of uniformity of layers and the use of 1-D methods at the North Anna site, using the R/B as an example, is justified because:

- The variation beneath the 309 ft x 213 ft structure is about 33 ft, i.e., the variation is not large compared to the plan dimensions.
- The concrete fill between the bottom of the foundation and the top of the Zone III-IV rock is designed to have a similar V_s to the Zone III-IV rock.
- The demarcation between the Zone III-IV and Zone IV rock is relatively random, reflecting the weathering process. Both zones are high quality rock.
- The variation in the top of competent (Zone III-IV) rock is irregular due to the weathering process, i.e., the rock profile is not dipping in the classical sense. This irregular profile is best modeled by a profile simulation (randomization) process.
- The soil profile simulation process involving 60 simulated profiles appropriately represents the variation of layer thicknesses and top of rock elevations for the 1-D model input across the footprint of each seismic Category I building.
- The variation of layer thicknesses and top of rock elevations across the entire site is addressed by considering different best estimate shear wave velocity profiles and layer thicknesses as well as their corresponding variations (described in terms of standard deviation) using the applicable boring data within and at close vicinity of the foundation footprint for each seismic Category I building.

Response to Question (b)

For the FIRS and SSI input motion spectra calculation, as described in response to Question (a), the variation of rock stratum thicknesses (top of rock elevations) across the footprint of each building is addressed by the soil profile simulation process involving 60 simulated profiles, which characterize the variation of the layer thicknesses and top of rock elevations. Moreover, the variation of layer thicknesses and top of rock elevations across the entire site is addressed by considering different best estimate shear wave velocity profiles and layer thicknesses as well as their corresponding variations (described in terms of standard deviation) for each seismic Category I building using the applicable boring data in the close vicinity of its foundation footprint.

The current GMRS for the NA3 site was defined at top of bedrock having a shear-wave velocity of more than 9,200 ft/sec. That definition used a common shear wave velocity and top of rock elevation across the entire site. However, in response to RAI 5198, Question 02.05.02-1, the GMRS was redefined at Elevation 250 ft corresponding to the deepest foundation elevation for seismic Category I structures (i.e., R/B and PS/Bs). Thus, the most relevant soil profile applicable for the GMRS calculation, which is characteristic of the entire site, is deemed to be the in-situ rock profile corresponding to the location of R/B and the East PS/B. The shear wave velocity profile and rock thickness variations were obtained from the three V_s borings within and close to the R/B and East PS/B footprints (B-901, B-907 and B-909 in FSAR Figure 2.5-237). Thus, similar to the FIRS calculation, the characteristic site variations are addressed in the calculation of the GMRS.

Proposed COLA Revision

None.

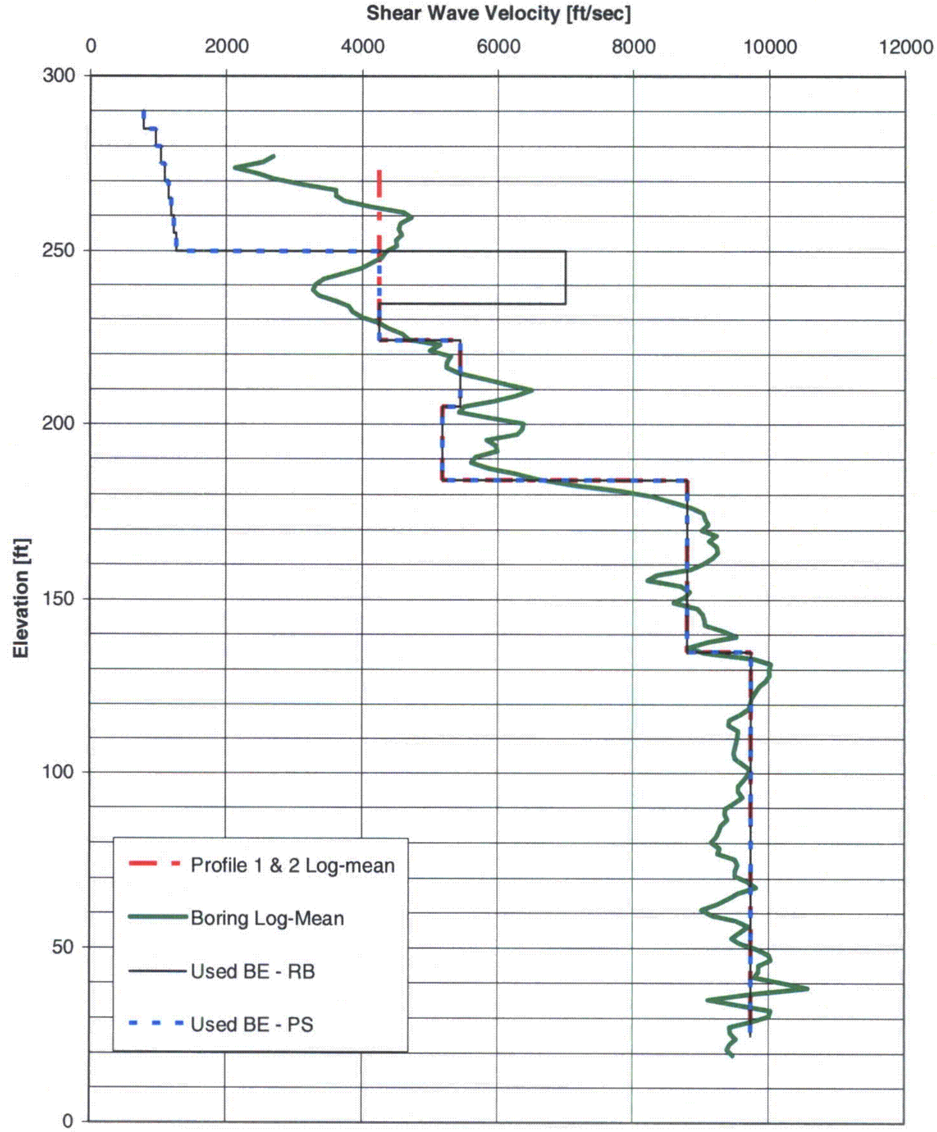

Figure 1 - Adopted Best Estimate Shear Wave Velocity Profile

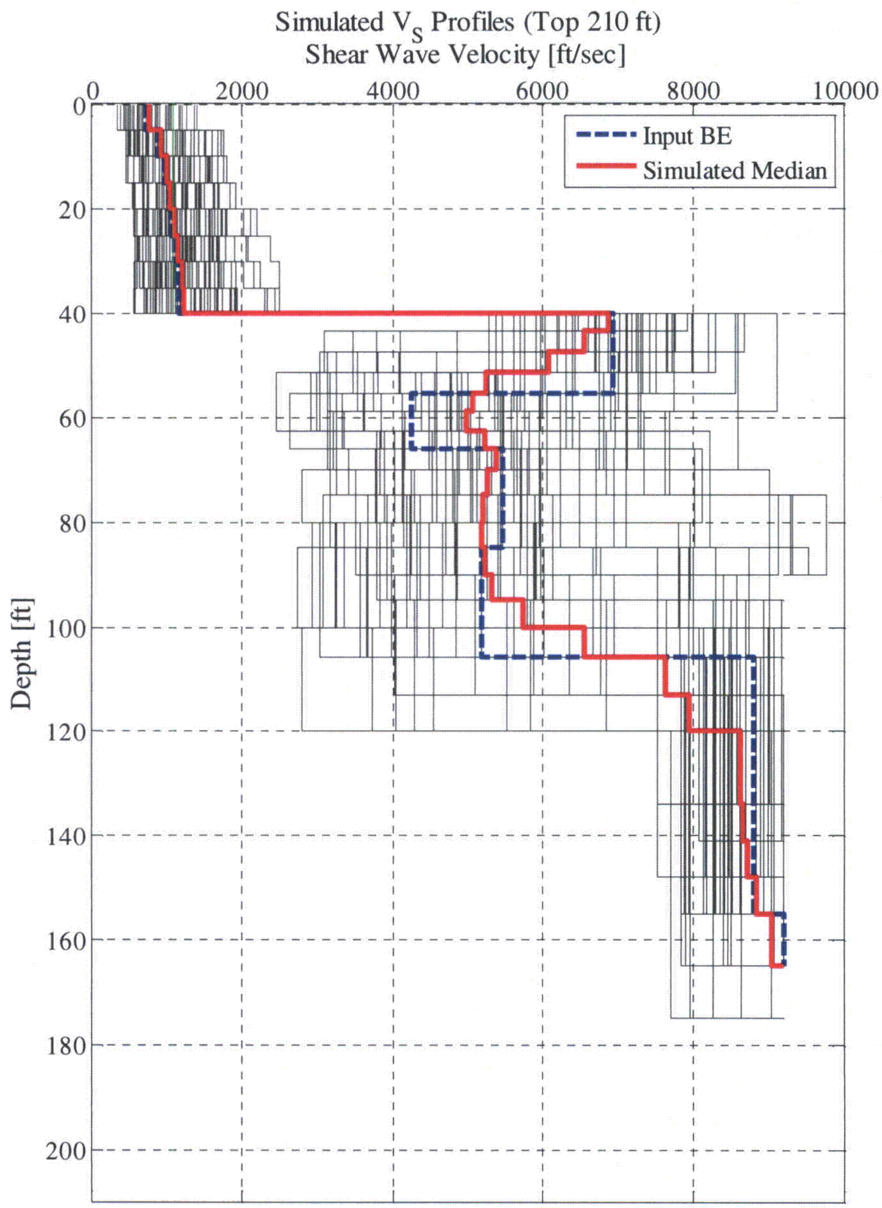

Figure 2 - Shear Wave Velocity for 60 Simulated Profiles for R/B Complex